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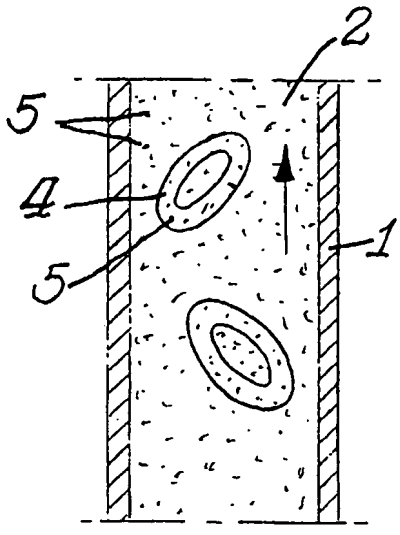
(54) Title: HEMODIALYSIS ASSEMBLY AND METHOD



(57) Abstract: A hemodialysis system and method of operation includes supplying whole blood containing blood cells, plasma fluid and foreign substances to a process control preferably having a centrifuge which operates to separate the cells from the plasma fluid and foreign substances. The plasma fluid and foreign substances are then conveyed away from the centrifuge where the foreign substances are removed from the plasma to result in cleaned blood cells and cleaned plasma fluid which may be used in a patient.

HEMODIALYSIS ASSEMBLY AND METHOD

Background of the Invention

Dialyzing whole blood, by various dialyzer configurations: coils, plates or tubes, etc. assumes that disequilibrium exists between red cell solutes and the plasma. The principle is that when whole blood is passed through the dialyzer, the solutes, under disequilibrium forces, expresses the cell solutes into the plasma which can then be removed through a permeable membrane along with the plasma solute. This concept is the reason for accepting a number of compromises negatively affecting the patient.

Such as:

Complement activation

Hemolysis

Emyloid bone diseases

Large doses of Heparin

First use of dialyzer cartridge problems

Solute clearance at about 10% of kidney function

There is evidence to support the theory that there is no driving force exerted on red cell solute during dialyzation. In effect, the red cells just go along for the ride. The cells and patient are compromised in the process.

In my copending parent patent application Serial No. 09/329,269 filed June 28, 1999, I disclose techniques for hemodialysis wherein the plasma fluid is separated from the cells (red blood cells, white blood cells and platelets). The cells are then returned to the patient. The plasma fluid is processed to remove contamination from the plasma fluid. This processing can be accomplished more readily and more quickly because the cells are not part of the fluid being processed.

Summary of the Invention

An object of this invention is to provide variations of my techniques disclosed in parent application Serial No. 09/329,269.

A further object of this invention is to provide a hemodialysis assembly and method which removes solute such as urea from the cells so that the solute is mixed only with the plasma fluid and whereby the solute can then be removed from the plasma fluid.

A still further object of this invention is to provide a hemodialysis assembly and method which would more closely approximate the clearance rate of normal kidneys. In accordance with this invention the solute present in the cells, particularly the red cells, is removed from the cells by a spin process such as centrifugation instead of dialyzation. The solute laden

plasma is then subjected to a processing to remove the solute from the plasma fluid.

Brief Description of the Drawings:

Figure 1 is a cross-sectional view in elevation showing the flow of blood through a tube before any treatment;

Figure 2 is a cross-sectional view showing blood after treatment in a centrifuge;

Figure 3 is a schematic view of an assembly for removing urea from plasma;

Figure 4 is a schematic view of an assembly for returning cleaned plasma and clean cells to a patient;

Figure 5 is a schematic view of an assembly in accordance with this invention of the continuous flow type;

Figure 6 is a schematic view of an assembly in accordance with this invention of an intermittent flow type; and

Figure 7 schematically shows the use of a treatment assembly for killing viral constituents in plasma fluid.

Detailed Description

Co-pending parent application Serial No. 09/329,269 filed June 28, 1999, all of the details of which are incorporated herein by reference thereto,

discloses a hemodialysis assembly and method for removing cells from plasma fluid and then returning the cells directly to the patient with the plasma fluid being treated to remove contaminants. Because the plasma fluid does not contain the cells, the processing of the plasma can be accomplished much more quickly and at much lesser expense than conventional practices where the contaminant removal processes plasma containing the cells. The present invention is directed to variations of the assembly and method described in that application. As described in the parent application the preferred manner of removing the cells from the plasma is in a spin process, preferably by means of a centrifuge. During the spinning of the centrifuge bowl the cells collect along the wall of the centrifuge bowl and the fluid plasma collects inwardly of the cells.

One of the difficulties that has been encountered in conventional dialyzing of whole blood is that solutes such as urea are found in the plasma and in the cells. Figure 1, for example, illustrates a tube 1 through which whole blood flows in the direction indicated by the arrow. The whole blood contained plasma fluid 2 and cells such as red cells 4. Urea 5 is present in both the plasma fluid and in the cells.

The present invention is based upon the recognition that foreign substances, such as urea, can be removed

from the cells, particularly the red cells when the cells are separated from the plasma. In the preferred practice of the invention the removal of the foreign substances is accomplished in a spinning process and more particularly in a centrifuge. While the invention will be particularly described with respect to urea as the foreign substance, it is to be understood that the invention may be practiced for removing other foreign substances or solutes, such as anti-viral substances which would be intentionally introduced into the blood for inactivating various types of viruses such as HIV, Hepatitis C and cancers. When the blood is to be reused these anti-viral substances are removed from the cells so that the cells are free of the substances. The substances which are then in the plasma fluid can later be removed from the plasma fluid.

Where a centrifuge is used for removal purposes the centrifuge can be rotated at typical speeds of about 4,000 rpm which would be of sufficient speed to separate the cells (red cells and white cells) from the plasma. If necessary higher speeds, such as 6,000 to 7,000 rpms would remove the platelets from the plasma. There is generally only an innocuous amount of urea with the platelets. Therefore, it may be sufficient to rotate at the lower speed of about 4,000 rpm rather than the hard speed of about 6,000-7,000 rpm. Thus, for practical purposes the

invention may be practiced where the urea is removed only from the red cells.

Figure 2 is a cross-sectional view of a centrifuge bowl 12 which may be used as part of a process control station as described in application Serial No. 09/329,269. Upon rotation of the centrifuge bowl 12 the cells, such as red cells 4, collect at the side of the bowl 12 while the plasma fluid 2 is concentrated inwardly of the red cells. The plasma fluid 2 is thus saturated with the urea 5 which had been removed or depleted from the cells 4. As later described, the urea depleted red cells can be removed from bowl 12 through a tube 14, while the urea saturated plasma could be removed through tube 16.

Thus, as illustrated in Figure 2, one of the features of the invention is to remove the solute such as urea from the red cells by a spin process, particularly centrifugation instead of dialyzation. The invention thus provides a new system configuration designed to maximize solute clearance from the plasma rapidly without the red cells being present, as will later be described. The system further fulfills the objective of providing a more closely approximation of the clearance rates of normal kidneys. For example, if one assigns a typical clearance rate of 1,000, used in the literature, for clearance comparisons, peritoneal dialysis is rated at 70. Typical

hemodialysis therapy reaches a level of 130. Spin dialysis could reach levels approaching 500. As later described, features of the system of the invention include:

a) A dual or single line from the patient, depending on physician's judgment.

b) Pass the whole blood through a sterile centrifugal bowl to separate the cells from the plasma. The high "g" forces created in the centrifuge would provide the driving force needed to remove the solute from the cells into the plasma.

c) Express the plasma from the cells as is commonly practiced for apheresis collection of plasma for fractionation.

d) Because the cells are absent, high throughput hollow fiber technologies could be maximized.

e) The cleaned plasma is connected to the cell return line, and both cleaned cells and cleaned plasma are returned to the patient.

f) This process can be continued until the physician is satisfied the level of solute clearance has been achieved. The use of Heparin could be reduced or eliminated.

Aside from the medical advances and patient care, the system uses modules that have been used as "Medical Devices" and cleared by the FDA for different end uses, for many years. Such known commercially available

modules include bowl separators, dialyzer cartridges, dialyzer equipment and sterile connection medical devices.

Figure 3 is a schematic view of various components of the system of this invention showing removal of the foreign substances, such as urea, from the plasma. As shown therein the urea concentrated plasma would be removed from bowl 12 through tube 16 and then through tubing 18 and fed into dialyzer 20 as described in parent application Serial No. 09/329,269. The urea would be removed by utilizing the saline dialysate techniques. This is illustrated in Figure 3 by the supply container 22 for the saline dialysate fluid which feeds the fluid through line 23 into dialyzer 20. On one side of a membrane 24 the urea would be chemically attracted and pass through the membrane into the dialysate and would then be discharged through line 26 to a waste collection area. If desired, a collection container 28 may be provided for the immediate collection of the urea laden dialysate. The cleaned plasma would be discharged from dialyzer 20 through line 30 into collection container or bag 32 as illustrated in Figure 3 or could be immediately redirected back to the patient as later described with respect to Figure 5.

Figure 4 illustrates the portion of the system of the invention used for returning the blood to the patient P. As shown therein the clean cells are removed

from centrifuge bowl 12 through tube 14 and then through passageway 34 back to the patient. The cleaned plasma such as from collection container 32 is used to supply cleaned plasma through outlet line 36 into passageway 34 and back to the patient.

Figure 5 illustrates a practice of the invention wherein there would be a continuous flow system for returning the blood to the patient. As shown therein a pair of generally permanently mounted tubes or lines 33,35 is provided in the patient. The outlet or patient discharge tube 35 is connected at a sterile connection 42 to blood feed tube 38 which directs the whole blood into the centrifuge bowl 12. As previously described the urea or various foreign substances are separated from the cells and remain in the plasma. The cleaned cells are then removed from bowl 12 through tube or passage 14 and into passageway 34 which is connected by sterile connection 42 to inlet line 33. The urea saturated plasma is removed from bowl 12 through tube or line 16 and into line 18 and then fed into the dialyzer 20 which is illustrated as a known hollow fiber dialyzer. In this embodiment the centrifuge 11 is a continuous centrifuge bowl separator.

Dialysate is fed from supply container 22 through line 23 into dialyzer 20 and urea plus any excess water are removed through line 26 into collection container 28. The cleaned plasma is discharged from dialyzer

20 through outlet line 30 and then into passageway 36 which communicates with passageway 34 for feeding the cleaned plasma back to the patient. Excess water may be removed by an ultra-filter either within the dialyzer or a separate filter.

Figure 6 illustrates the practice of the invention as a single line dialyzer system which operates on the intermittent flow principle. As shown therein a single permanently mounted tube 37 in patient P would be connected by sterile connection 42 to tube or passageway 34. At one stage of operation the whole blood would be removed from the patient through tube 37 and passageway 34 and fed into the batch centrifuge bowl separator 13 through line 14. Upon rotation of the bowl 12 the urea is removed from the cells and the cleaned cells are separated from the urea laden plasma. The operation is then reversed so that the cleaned cells can be removed through tube 14 and fed back into the patient through passageway 34 and tube 37. In the meantime, the urea concentrated plasma is removed through tube 16 and fed through passageway 18 into hollow tube dialyzer 20. The dialysate is fed from supply container 22 through line 23 into dialyzer 20 and the dialysate containing the urea is discharged through line 26 into collection container 28. The cleaned plasma is removed through discharge tube 30 and collected in container 32 as previously described. The cleaned

plasma is then fed from container 32 through line 36 which communicates with line 34 for feeding the cleaned plasma back to the patient.

As is apparent both the continuous flow system of Figure 5 and the intermittent flow system of Figure 6 provide a sterile flow system. Although not illustrated, the various modules and their connecting plastic tubing could be connected to other modules and their plastic tubing by appropriately located sterile connections so that the individual modules may be removed and replaced by other modules as described in parent application Serial No. 09/329,269.

As should be apparent the present invention thus provides a hemodialysis system or assembly and method of operation which effectively cleans the cells, particularly the red cells by removing foreign substances such as urea or even substances which have been intentionally added, such as anti-viral substances. Foreign substances which have been removed are then carried by the plasma fluid and in a plasma processing step the foreign substances are later removed from the plasma fluid to provide both cleaned cells and cleaned plasma which can be reused for a patient.

The invention particularly lends itself for home care use.

In addition to reducing dialysis time by collecting the plasma in containers such as plastic bags which may be used for collector 32, it is possible to subject the plasma to conventional heat treating or radiation to kill constituents such as HIV, HBV, HCV, HAV, Hepatitis A virus, Hepatitis B virus, Hepatitis C virus, and viruses that have been documented to be transmitted by blood transfusions and other routes, as well as other viral or bacterial infections. If the cells were present, such sterilization treatments would not be possible because of cells destruction. Thus the invention may be practiced to reduce the uncontrolled HIV spread within the body by removing viral elements from the treated plasma. This technique is control therapy not an HIV cure. It prevents HIV+ from becoming AIDS.

In such practice of the invention, as shown in Figure 7, the bag 32 containing the plasma which includes viral constituents is placed at or near a treating assembly 44 which utilizes the application of radiation or heat treatment to kill the viral constituents in the plasma. This aspect of the invention could be used where the separated plasma and viral constituents are conveyed directly to a container, such as bag 32, and then subjected to the treatment. Alternatively, the invention could be practiced where the separated plasma and viral

constituents are first conveyed to a dialyzer ultra-filter to remove other foreign substances and then the processed plasma which may still contain minute quantities of active viral constituents are conveyed to bag 32. The viral constituents are then killed by treating assembly 44.

The invention thus provides techniques whereby the various foreign substances in the plasma which had been removed from the cells could later be removed from the plasma fluid so that both the cells and the plasma are free of these substances.

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What is Claimed is:

1. A hemodialysis system comprising an upstream tube for supplying blood containing blood cells and plasma fluid and foreign substances, said upstream tube being in communication with a process control, said process control including separating structure for separating the foreign substances and the plasma fluid from the cells, said process control including a return tube for removing the cleaned cells from said process control, a dialyzer, said dialyzer containing removing structure for removing the foreign substances from the plasma fluid, and a plasma return tube leading from said dialyzer for conveying uncontaminated plasma fluid discharged from said dialyzer.

2. The system of claim 1 wherein said separating structure comprises a centrifuge.

3. The system of claim 2 wherein said removing structure comprises a dialysate supply container having a dialysate supply tube leading to said dialyzer for suppling a

dialysate into said dialyzer and a dialysate discharge tube leading from said dialyzer.

4. The system of claim 2 including a patient discharge tube communicating with said upstream tube for supplying blood from a patient to said process control, a patient inlet tube in communication with said return tube for supplying clean cells to the patient, and a clean plasma return tube communicating with said patient inlet tube for supplying clean plasma to the patient.

5. The system of claim 4 wherein said patient discharge tube and said patient inlet tube are separate tubes, said upstream tube and said return tube being separate tubes, said clean plasma returned tube communicating with said plasma return tube to supply clean plasma from said dialyzer to the patient in a continuous flow operation, and said centrifuge being a continuous centrifuge bowl separator.

6. The system of claim 4 wherein said patient discharge tube and said patient inlet tube

comprise the same tube, said upstream tube and said return tube comprising the same tube, said plasma return tube leading to and communicating with a plasma connector, said clean plasma return tube leading from said plasma collector to said patient inlet tube to provide an intermittent flow operation, and said centrifuge being a batch centrifuge bowl separator.

7. The system of claim 4 wherein said clean plasma return tube and said return tube communicate with each other to form a combined discharge tube, and said combined discharge tube communicating with said patient inlet tube.

8. The system of claim 7 wherein said combined discharge tube is connected to said upstream tube by a sterile connection, and said patient inlet tube being connected to said combined discharge tube by a sterile connection.

9. The system of claim 7 wherein said upstream tube and said return tube comprise a single tube, and said combined discharge tube

being connected to said patient inlet tube by a sterile connection.

10. A hemodialysis system comprising an upstream tube for containing blood having blood cells and plasma fluid and viral constituents, said tube being in communication with a process control, said process control including separating the structure for separating plasma fluid from the cells, a plasma collector, a downstream tube leading from said process control to said plasma collector, and treating structure operatively communicating with said plasma collector for killing off the viral constituents in the plasma fluid.

11. The system of claim 10 wherein said separating structure comprises a centrifuge.

12. The system of claim 10 wherein said treating structure is a heat treating assembly.

13. The system of claim 10 wherein said treating structure is a radiation application assembly.

14. A method of hemodialysis comprising providing an upstream tube for supplying

whole blood containing blood cells and foreign substances and plasma fluid from the patient, flowing the whole blood to a process control, separating the plasma fluid and the foreign substances from the blood cells by use of separating structure in the process control, flowing the plasma fluid and foreign substances to a collector, and removing the foreign substances from the plasma fluid to obtain uncontaminated plasma fluid.

15. The method of claim 14 wherein the plasma fluid and foreign substances are separated from the cells by a centrifuge having a bowl which causes the cells to collect on the side of the centrifuge bowl while the plasma fluid and foreign substances collect inwardly of the cells.

16. The method of claim 14 wherein the foreign substances are urea and the collector is a dialyzer, and removing the urea from the plasma fluid by means of dialysate in the dialyzer.

17. The method of claim 14 wherein the foreign substances are anti-viral substances.

18. The method of claim 14 wherein the upstream tube communicates with a patient for supplying the whole blood from the patient to the process control, returning the cleaned blood cells from the centrifuge bowl to the patient, and feeding cleaned plasma fluid to the patient.

19. The method of claim 18 wherein the cleaned blood cells and cleaned plasma fluid are returned to the patient in a continuous flow process.

20. The method of claim 18 wherein the cleaned blood cells and the cleaned plasma fluid are returned to the patient in an intermittent flow process through the same tube which supplies the whole blood from the patient to the process control.

21. The method of claim 14 wherein the foreign substances are viral constituents which are removed from the treated plasma to control viral proliferation.

22. The method of claim 21 wherein the method is used to reduce uncontrolled HIV spread within the patient to reduce HIV + becoming AIDS.

23. The method of claim 14 wherein the foreign substances are viral constituents which are removed from the plasma fluid by a heat or radiation treatment which kills the viral constituents.

24. A method of hemodialysis comprising supplying blood cells and foreign substances to a separating station having spinning structure, spinning the spinning structure to separate the blood cells from the foreign substances, conveying the foreign substances to a collecting station downstream from the separating station, and collecting the foreign substances.

25. The method of claim 24 wherein plasma and the foreign substances are separated from the blood cells in a centrifuge which comprises the spinning structure, and removing the foreign substances from the plasma in the collecting station by means of a filter.

26. The method of claim 25 wherein the foreign substances are anti-viral substances.

27. The method of claim 24 wherein plasma and the foreign substances are separated from the blood cells in a centrifuge which comprises the spinning structure, and the foreign substances are anti-viral substances.

28. A hemodialysis system comprising a centrifuge for receiving blood cells and foreign substances, said centrifuge being rotatable to separate the blood cells from the foreign substances, a collecting station downstream from said centrifuge for receiving the separated foreign substances, and said collecting station having collecting structure for collecting the foreign substances.

29. The system of claim 28 wherein said collecting structure is filter structure.

Fig. 3.

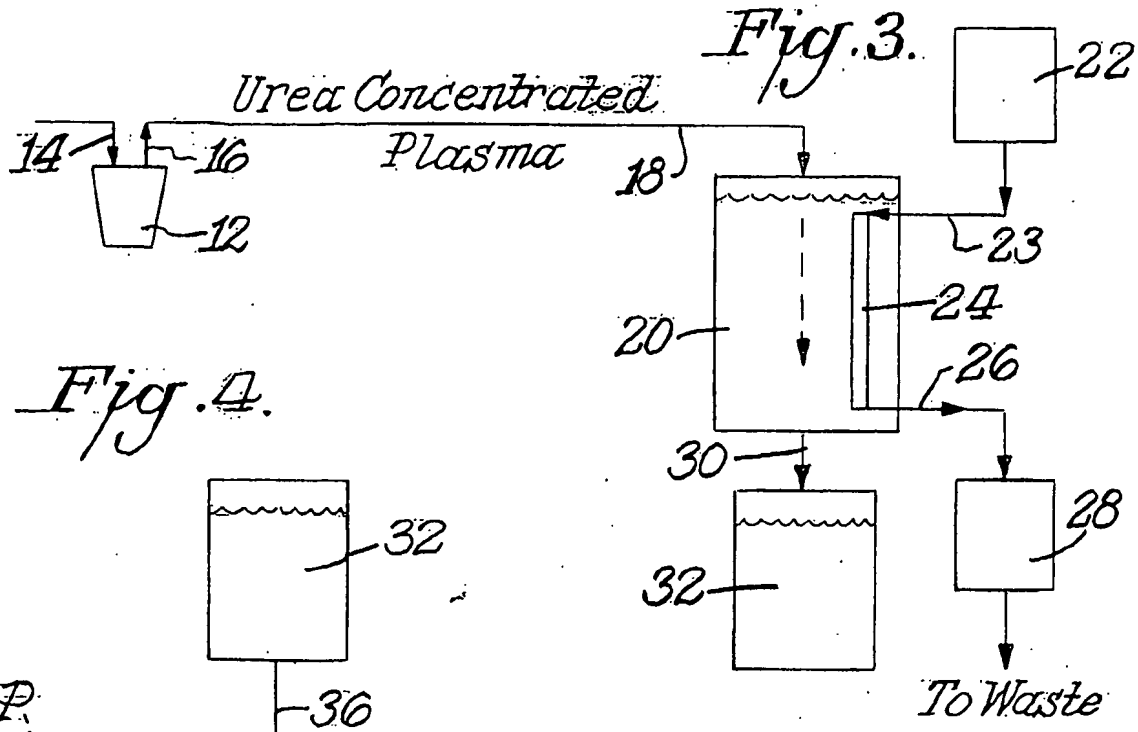

Fig. 4.

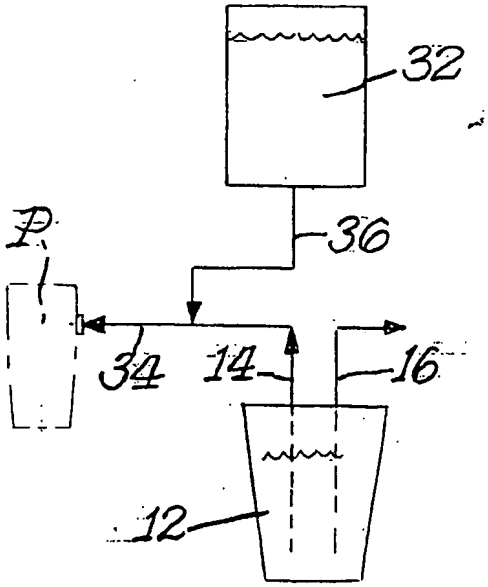

Fig. 2.

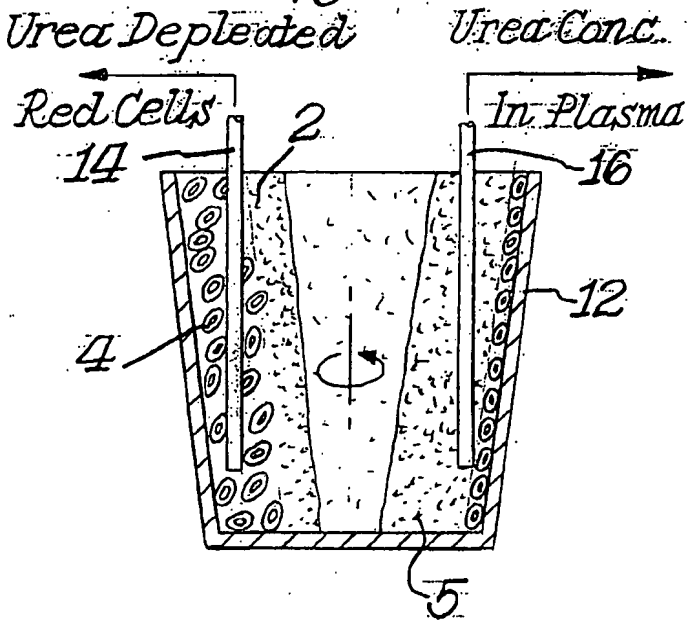

Fig. 1.

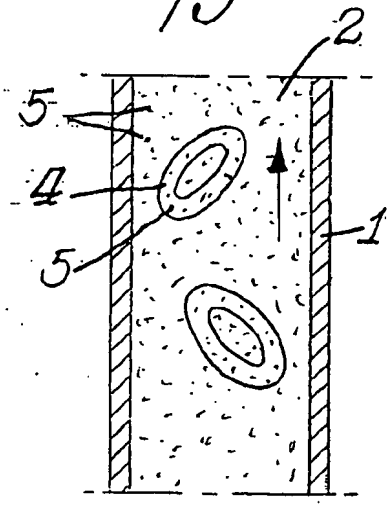

Fig. 5.

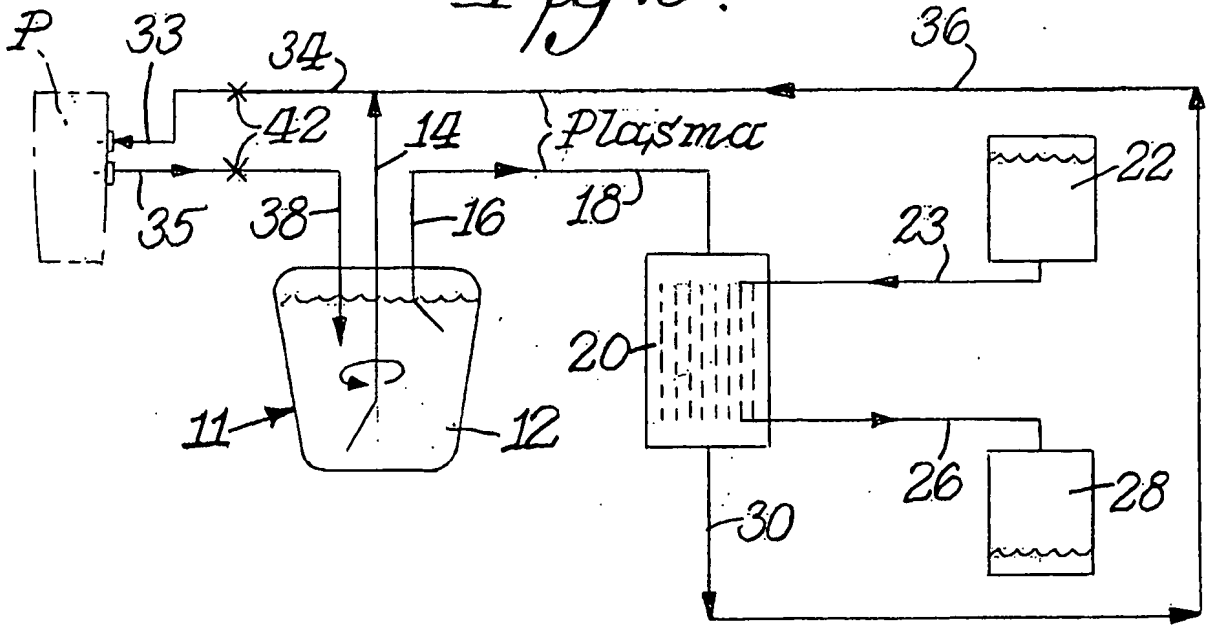
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Fig. 6.

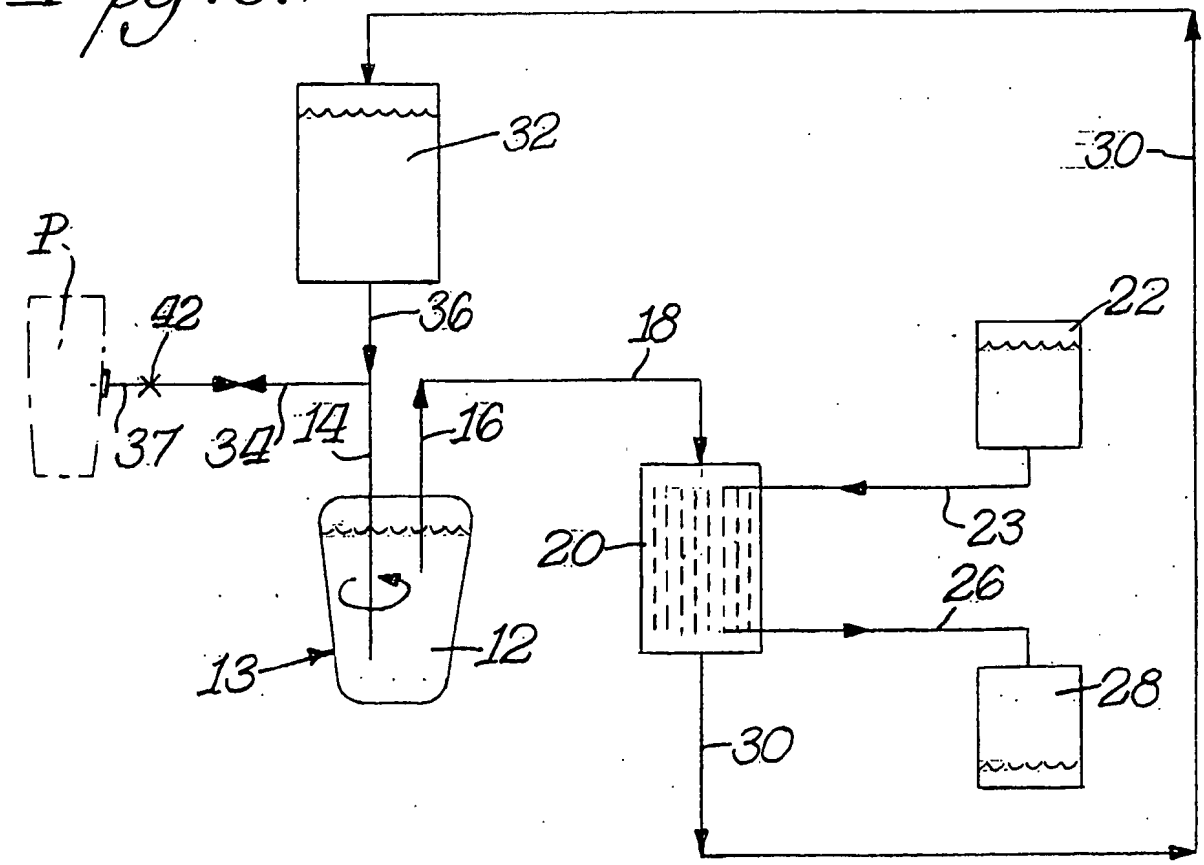
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Fig. 7.